Customer No. 27061 Patent
Confirmation No. 1362 Attorney Docket No. GEMS8081.198

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of	:	Toth et al.
Serial No.	:	10/765,618
Filed	:	January 27, 2004
For	:	SYSTEM AND METHOD OF COLLECTING IMAGING SUBJECT POSITIONING INFORMATION FOR X-RAY FLUX CONTROL
Group Art No.	:	2882
Examiner	:	Hoon K. Song

CERTIFICATION UNDER 37 CFR 1.8(a) and 1.10

I hereby certify that, on the date shown below, this correspondence is being:

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□ deposited with the US Postal Service in an envelope addressed to Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450

37 CFR 1.8(a) **37 CFR 1.10**

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□ transmitted by facsimile to Fax No.: 571-273-8300 addressed to **Examiner Hoon K. Song** at the Patent and Trademark Office.

■ transmitted by EFS-WEB addressed to **Examiner Hoon K. Song** at the Patent and Trademark Office.

Date: August 31, 2007 /Robyn L. Templin/
Signature

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

DECLARATION UNDER 37 C.F.R. §1.131

We, being duly sworn, depose and say:

1. That we are the inventors for the above-identified Patent Application;

2. That we have reviewed the claims of this Application;

3. That we conceived the invention as set forth in the aforementioned claims in the United States prior to October 17, 2003, the effective date under 35 U.S.C. § 102(e) of the cited United States Patent Application 2005/0085710 to Earnst et al.;

4. That, prior to said date, we conceived of a method of imaging that includes positioning a subject in an imaging device, collecting positioning information of the subject from at least one sensor

disposed in proximity of the imaging device, and determining a relative position of the subject within the imaging device from at least the position information.

5. Attached as Exhibit A is a copy of our disclosure to our employer that was prepared prior to October 17, 2003 and evidencing this invention;

6. That from prior to October 17, 2003 to January 27, 2004, the filing date of the above-reference Patent Application, we diligently worked toward reducing the aforementioned inveniton to practice and worked with patent counsel in the preparation of a patent application of the claimed invention; and

7. That the statements made herein are of our own knowledge and are true and made on information and belief that are believed to be true.

We acknolwedge that any willful false statements and the like made herein are punishable by fine or imprisonment, or both and may jeopardize the validity of the application or any patent issuing thereon.

Thomas L. Toth

Date: 8/17/07

David M. Hoffman

Date: 8/20/07

GE Medical Systems
Invention Disclosure Form

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Docket No.: 143502

Mail to: PATENT OPERATION, W-710

Date Received: [redacted]

- **Use as many pages in this word document as necessary.**
- **You may attach additional materials to support this disclosure, for example, Tech Notes and Drawings. Such submitted materials must be referenced in this disclosure form. Each page of these materials must be dated, signed and witnessed in the same manner as this invention disclosure.**

MODALITY: *(e.g., CT, MR, Ultrasound, X-Ray)*

CT

INVENTION TITLE: *Provide a unique, descriptive title. If you write this disclosure in a language other than English, please provide a title in English as well. Si vous rédigez en français, merci de proposer un titre en anglais et un titre en français.*

CT X-ray flux management control methods

PROBLEM/BACKGROUND: *Describe the problem that is solved by the invention. Assume that the reader has a basic knowledge of your diagnostic imaging modality and related technologies.*

Current CT practice uses a bowtie filter and mA modulation (automa) to shape the intensity of the x-ray beam incident to the patient. The intent of the bowtie filer is to minimize X-ray exposure to edges of the patient where path lengths are shorter and noise in the projection data is a less important contributor to overall image quality. However, improper patient centering and/or bowtie filter selection can significantly degrade image quality and dose efficiency. The bowtie filter projects the maximum x-ray intensity to isocenter and attenuates radiation significantly with radial distance beyond the flat region of the bowtie (Fig 1). If the patient is not centered, significant image degradation will occur depending on the size of the bowtie opening, size and shape of the patient, and the amount and direction of patient miscentering. Image degradation occurs if the bowtie opening is too small for a large patient since useful x-ray needed for imaging is attenuated by the bowtie causing high image noise.

If the patient is mis-centered in an otherwise properly sized bowtie, image degradation can occur in current state of the art CT systems as a result of two factors. First, if automA (Z axis tube current modulation) is calculated from a 12:00 AP scout and patient miscentering is caused by low table elevation (a common source of miscentering), then automa will under estimate the patient size since the projection area will be under stated because the patient intercepts fewer rays in the fan beam projection (see Fig 2). This will cause the system to use less mA than required, resulting in excessive image noise relative to the user's selection. A 30% low mA prediction occurs for a typical 30 cm x 20 cm body miscentered in elevation by 3cm resulting in a 15% noise increase.

Secondly, a more devastating effect for current state of the art CT occurs since patient miscentering in Y will position the thickest part of the patient such that x-rays for lateral projections must also pass through the thickest part of the bowtie (Fig 3). This miscentering results in an additional image noise increase by as much as 70% in some cases. These errors can cause images of such high noise that the diagnostic value is compromised.

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Another problem is related to the desire to use photon counting and energy discriminating detectors (EDCT) instead of the photon energy integrating detectors used in current commercial CT systems. EDCT systems have the potential to greatly increase the medical benefits of CT by differentiating materials (such as contrast agent in the blood and calcifications) that may otherwise be indistinguishable because conventional CT produces similar Hounsfield Unit values. In addition, photon counting and EDCT produce less image noise for the same dose than photon energy integrating detectors and hence can be 30% more dose efficient that conventional CT.

Current state of the art photon counting and EDCT detectors have photon counting rate limits of about 1 mHz. While these rates are more than adequate for making high quality CTimages (i.e count rates of 50 kHz to 200 kHz through the central section of the patient), the dynamic range of photons at the edge of the patient can easily exceed 10 mHz. This large photon flux range in patient projection data precludes the use of current state of the art photon counting or energy discriminating detectors for CT. A means to control a continuously variable bowtie filter would be a break through solution enabling the introduction of commercial EDCT systems.

INVENTION DESCRIPTION: *Describe how the invention works and how it solves the problem posed above.*

This invention provides a means to calculate the patient's size, shape, and centering from one or two scouts and to use this information to provide centering information to the user, automatically re-center the patient elevation, correct projection area measurements for automa calculations, select the correct bowtie filter for the optimum dose efficiency and to provide x-ray flux management for EDCT systems.

Various methods to determine patient centering and tube current modulation are known (see prior art section). However, none of these methods addresses the selection of the proper bowtie filter opening or the impact of the bowtie filter and patient mis centering on tube current (x-ray flux) modulation. Fig 4 is an integrated summary of the methods disclosed herein.

In (A) of fig 4 we describe a dynamic bowtie and tube current adjustment method. In (B) we use one of the scout scan methods (E), (I), or (M) to determine the required tube current modulation in X,Y and Z for the desired image noise assuming a properly centered patient. Depending on the orientation of the available scout(s), we select a starting CT scan angle, Z location and positions for the left and right filter segments of a continuously variable bowtie filter such as described in docket 1442221. The starting filter positions are determined independently for each side in accordance with the methods described in (H) and/or additionally to maintain the x-ray flux rates below the absolute maximum limit of the of an EDCT detector (Fig 5). X-ray rates for photon counting and energy discriminating detectors are significantly lower than for the photon energy integrating detectors in current CT practice. Hence flux rates must be carefully managed to avoid count rate saturation (photon pileup). Since patient attenuation, projection centering error and desired flux rate levels are known; x-ray flux rates can be controlled by appropriate filter positioning and mA adjustment using expressions representing the fundamental x-ray physics attenuation and absorption equations.

This is accomplished in (C) of Fig 4 for the start scan projection using scout scan information and for subsequent projections during the CT scan using flux rate trends from prior views to supplement a priori attenuation and modulation patterns predicted from the available scout scans. A priori dynamic filter positioning can be calculated based on the optimum FW for patient centering and by using patient ellipse parameters *a* and *b* as orthogonal diameters in the methods described in detail later. Filter positioning can also be adjusted dynamically by sensing the maximum flux rate at the patient edge regions and using a closed loop feed back system. As the maximum flux at the object edge increases, the associated filter segment is

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moved toward isocenter an appropriate amount to maintain a desired edge flux rate. As the maximum flux at the edge of the object decreases, the associated filter segment is moved away from isocenter to restore the desired flux rate. At the same time, the tube current (mA) is increased or decreased to maintain the desired mean x-ray flux rate in the central projection region between the patient edge regions. Since mA modulation also influences the edge flux, it is preferable to control edge flux levels relative to the average central flux level (or use apriori positioning) for routine dynamic bowtie positioning with a feed back loop and to use filter positioning moves to prevent photon counting pileup only when absolute flux limitations are at risk. In this way the bowtie can be positioned for optimum dose efficiency based on the patient size, shape and centering as a first priority with positioning for prevention of photon pileup functioning as a backup. For situations where the central projection region may have the highest x-ray flux, such as for AP projections when scanning legs, adjusting the mA to avoid photon counting pileup in the center of the projections would have priority over the usual tube current modulation objectives for IQ and dose.

Bowtie position information is collected and included for each projection during the scan to allow the bowtie attenuation profile to be properly normalized during image reconstruction. Bowtie positioning repeatability must be maintained within 10 micrometers to allow dynamic calibration and correction of the moving bowtie during patient scanning.

Referring now to fig 4 (E), the most reliable patient size and centering determination can be made from the projections using two orthogonal scouts vs a single scout. Although the centering can be determined as indicated in US 5,457,724, another more accurate method is to calculate the centroid (center of mass) from the two orthogonal scout projections (F). The distance of the centroid from the isocenter channel can be used to geometrically calculate the X and Y centering error for the patient. Use of centroid calculations is better than edge detection methods since it yields the center of maximum attenuation that should be positioned in the maximum X-ray field rather than just the physical center relative to the edges of the object.

Having calculated the y axis patient centering error over the extent of the prescribed CT scan, the system can calculate the mean center, to provide the optimum fixed table height for the duration of the CT scan (Fig 6). The user would be notified of the centering error (F) and could accept or reject the table elevation change or use a graphical indication or other means to indicate the most appropriate centering for the type of study. For example a spine study (Fig 6) would be optimally centered on the spine instead of the overall attenuation centroid for the patient. The user could mark the location of the spine or other organ of interest (such as the heart) on the scouts using a cursor marker (fig 7). The table could be raised and lowered dynamically during the execution of a helical CT scan to accommodate the changing optimum elevations depending on patient anatomy as in US 6269501 B1. Elevation data would be included in the scan data header to properly position the views during image reconstruction. If a continuous bowtie is present, the bowtie can be positioned dynamically to follow the sineogram of the the patient. If the location of an organ of interest is designated, the bowtie can be dynamically positioned to follow the sineogram of the organ of interest. This positioning obtains optimum image quality for the organ of interest and minimize dose elsewhere. This is an enhancement of the organ specific bowtie idea described in docket 125908.

In (G) of fig 4, the X and Y centering errors can also be used to correct the projection area (PA) for automA calculations. AutomA calculations are described in docket 142942 (filed on Aug 13, 2002). The PA is the sum of the attenuation values of the rays that intercept the patient and hence it is dependent on the distance of the patient from the fan beam x-ray source. We can therefore directly calculate the correct PA using basic geometric equations, since the PA of the projections represents the area of an elliptical model of the patient and the centering error gives us the actual patient to source distance (Fig 2). The PA from both the AP and lateral scouts can be corrected using the centering error determined from the orthogonal scout and the average AP and lateral PA can be used to improve the accuracy of the automa noise prediction algorithm. Similarly the oval

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ratio (OR) can be directly computed using the PM ratio from the two orthogonal scouts to further improve the accuracy of the automA noise prediction algorithm.

The proper bowtie filter is then selected in (H) of fig 4. For a given bowtie filter shape (for example the shape described for a continuous bowtie filter in docket 142221) and a given patient size and shape there exists an optimum opening (FW or flat width) that provides the best image quality at the lowest dose. The optimum is the value of FW that maximizes a quality factor Q as follows:

$$Q = \frac{KC(d, FW)}{N(a,b,FW)\sqrt{D(a,b,FW)}}$$

Where

N is the overall noise in the image or scan data (standard deviation)

D is the dose to the object

C is the contrast between two materials such as iodine and water (dependent on the spectral characteristics of the system)

K is the contrast weighting factor.

a and b are the axes parameters for an ellipse

FW is one half of the flat width (i.e. ½ the length of the uniform low attenuation region of the bowtie filter in mm)

Another form of the quality factor equation uses as a single diameter parameter d, where d is the average of a and b

$$Q = \frac{KC(d, FW)}{N(d,FW)\sqrt{D(d,FW)}}$$

The optimum opening can be determined experimentally by constructing various phantom sizes and shapes and then scanning the phantoms with various bowtie filters having different FW opening values, reconstructing images, measuring the noise, dose, and contrast for each case, and fitting a curve to the Q values vs FW. The optimum FW for a given patient size is the FW value where Q is maximum (Fig 8 left). The Q values can also be determined by computer modeling using the fundamental X-ray physics attenuation and absorption equations to estimate the noise, contrast and dose in the image for each case. The contrast weighting value K can be chosen between 0 and 1. In our implementation we chose the value of K to be zero in order to exclude any benefits of improved object contrast although contrast increase benefits are very significant. We excluded the benefits of contrast since there is currently there is no authoritative study that indicates radiologists will reduce technique factors (hence dose) in response to a contrast improvement. However, it is well known that radiologists are willing reduce technique factors in response to image noise improvements. Hence we calculate a bowtie opening that produces the lowest image noise at the lowest dose.

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From experimental data or simulations a set of optimum bowtie opening values can be determined vs patient or object size as shown in Fig 8 (right). The relationship is approximately linear and can be represented by the equation *FW =0.45 (d-10)* for the K=0 assumption where *d* is the patient diameter in cm. Patients with diameters less than 10 cm would use a bowtie opening FW value of zero.

For patient scanning we can use the equation to select the optimum bowtie opening FW given the patient diameter *d*. The patient diameter can be determined from the PM (automA algorithm) and patient density assumption μ. Since we can obtain the average PM from the orthogonal scout scan pair, we can calculate the diameter since $d = avg(PM/\mu)$ from x-ray attenuation physics. For the human body, the density assumption μ can be assumed to be 0.2 (attenuation coefficient of water) except for the chest and head. For the chest and head μ can be approximated as 0.14 and 0.24 respectively due to the density decrease of the lungs and the density increase of the skull.

For CT systems with a continuously variable addressable bowtie, the FW value can be determined directly by the equation. On CT systems without an addressable continuous bowtie (current state of the art) the equation can be used to select the nearest optimum bowtie from the selection of available discrete bowtie filters. For example a good set of discrete bowtie filters that covers the patient range from infants to large obese adults (assuming reasonable centering) would consist of bowtie filters with a shape as defined docket 142942 and openings with FW values of 1, 5, 9 and a flat filter. From the graph on fig 8 (right), we can construct the following lookup table to select the most optimum discrete bowtie for the patient as follows:

Diameter	<15 cm	15 to 25 cm	> 25 to 35 cm	> 35 cm
Bowtie	FW 1	FW 5	FW 9	flat

The optimum filter opening, however, is dependent on how well the patient is centered in addition to the patient's diameter. The effect of patient miscentering is comparable to a patient radius increase for the projections perpendicular to the miscentering axis. Hence the proper filter selection is a function of the patient diameter plus the miscentering and can be determined using *FW = 0.45 (d-10+2ew)* where *e* is the patient mis centering error in cm and w is a weighting factor or function. The weighting factor is typically 1.0 but could be less than 1.0 to constrain the dose increase that would otherwise result when the bowtie is opened to fully account for the worst case effect of miscentering. The value of w could also be a function of the object size, shape and miscentering to more closely match the behavior of image noise with miscentering of various size objects. A discrete bowtie selection can also be obtained by adding the centering error factor (*2ew*) to the phantom diameter for the lookup table index.. For example, from the table a 24 cm patient with a 3 cm error would be considered a 30 cm diameter and hence would select filter FW 9 instead of FW 5 for the centered case.

In the event that automA is used and the patient is miscentered in a smaller than optimum bowtie, the mA can be boosted to avoid an unacceptable noise increase in the image. [redacted]

Refering to (I) of fig 4, we have the case where only a lateral patient scout is available. In (J) we calculate the y miscentering and assume the x miscentering is 0. This is reasonable since the technologist has the edges of the patient table to use as a

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guide when positioning the patient in x. In (K) we calculate the PA, PM and OR from a single scout using known methods. In (L) since we only have one PM from a single scout we can determine the diameter for bowtie selection using determination we can use $d=(PM/\mu)(OR+1)/2$ since OR is the ratio of the axis parameters of the elliptical patient model. We then select the appropriate bowtie, calculate the mA modulation, and the mA boost factor based on the y axis centering information using known methods and methods previously described herein.

Referring to (M) of fig 4, we have the case where only an AP patient scout is available. Therefore, the Y axis centering error can not be directly determined since it is in the same orientation as the scout projections. However, we can still estimate the y axis error if we have elevation information relative to the surface of the patient.

Surface elevation information about the patient can be obtained in one of two ways as shown in fig 9 A and B. If the patient is resting directly on the patient cradle, we can use the table elevation to determine Y axis centering error. However, in cases where the patient is propped up with pillows or other positioning devices (for clinical reasons) the centering can be determined from a laser or sonic displacement measuring device positioned on the gantry to locate the top surface of the patient. A vector of position information is collected and associated with each scout projection to allow the centering error to be calculated as a function of Z.

In (O) of fig 4, we calculate the PA corrected for Y axis centering error. This can be done by direct geometric calculations or as a fitted function of elevation, PA, and OR as shown in Fig 10. In (P) we can select the bowtie, calculate the mA modulation and boost the mA for miscentering as described previously herein.

In (Q) of fig 4, we assume the patient is centered and select the bowtie based on patient size estimated from the PM and density assumption of μ as previously described herein. The mA modulation is calculated from a single scout using known methods

In (R) of fig 4 we do not have any scout information about the patient but we have distance information from a set of fixed points on the gantry from which we can estimate the patient's external contour. Distance information can be obtained from a set of lasers or sonic sensors as in C of Fig 9. In (S) fig 4 we can determine the PA, OR and miscentering. The PA can be determined from the external patient contour and the μ for the associated anatomy as described previously herein. The OR is determined directly from the distance measurements or from the PM which can be determined from the μ and patient surface distances. Miscentering is determined by measuring offset of the contour projections from isocenter. The bowtie is then selected , mA modulation calculated and mA boosted for miscentering in (T) as previously described herein.

If we do not have any information about the patient's size, attenuation, or centering, (U) the user manually selects the bowtie and fixed mA protocol scanning methods.

DRAWING: *Make as accurate a sketch or computer generated figure of your invention as you can and embed it into or attach it to this form. It need not be a drawing to scale, but should be complete enough to show what you have in mind. If you already have suitable photographs, sketches, software flowcharts or finished drawings, they may be used.*

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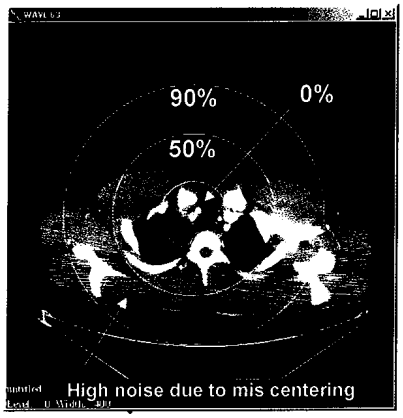
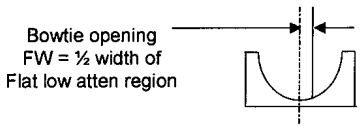
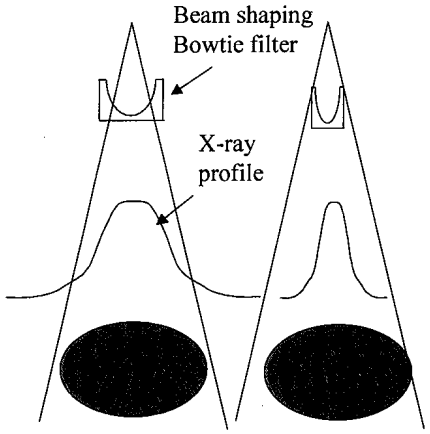
Figure 1



% Effective mA reduction contours with a standard body bowtie filter

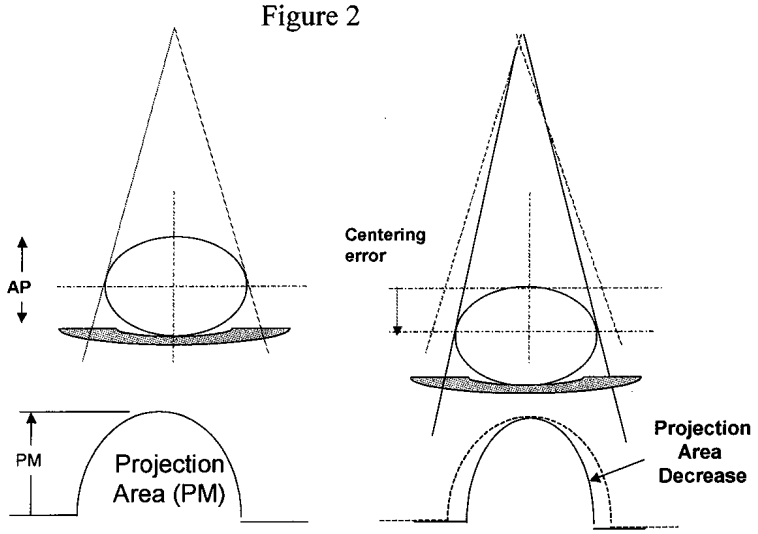




Bowtie opening Matched to patient

Bowtie opening Too small for patient

Figure 2



Projection area is underestimated if table elevation is Low with an ap scout (tube at 12:00)

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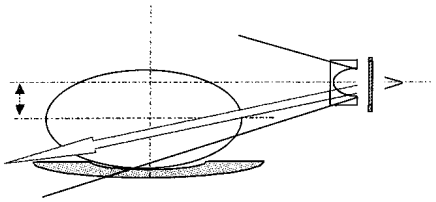
Figure 3



Thickest part of patient intersects thickest part of bowtie filter

Figure 4

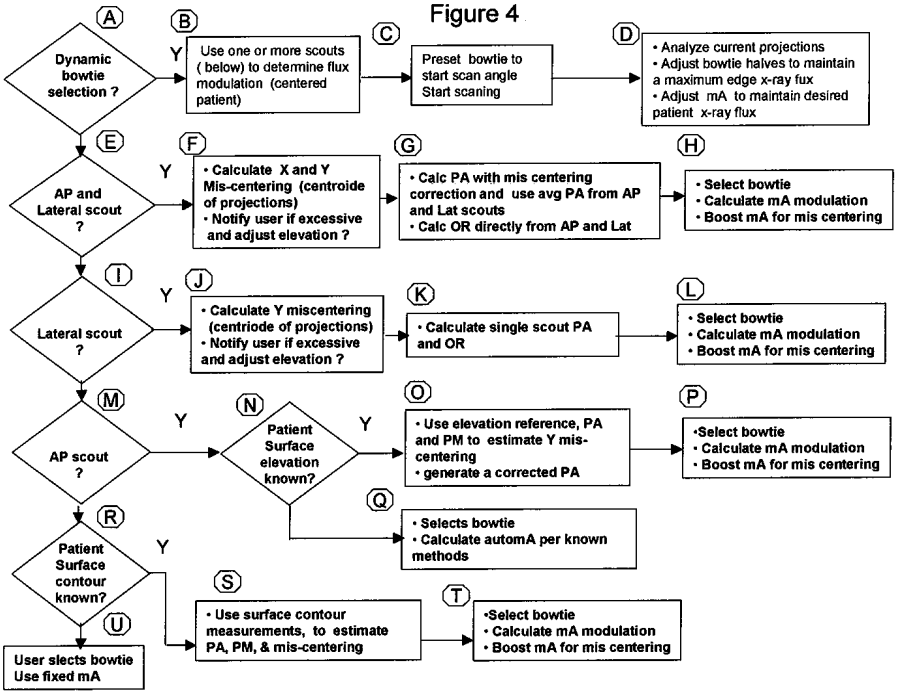


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Figure 5

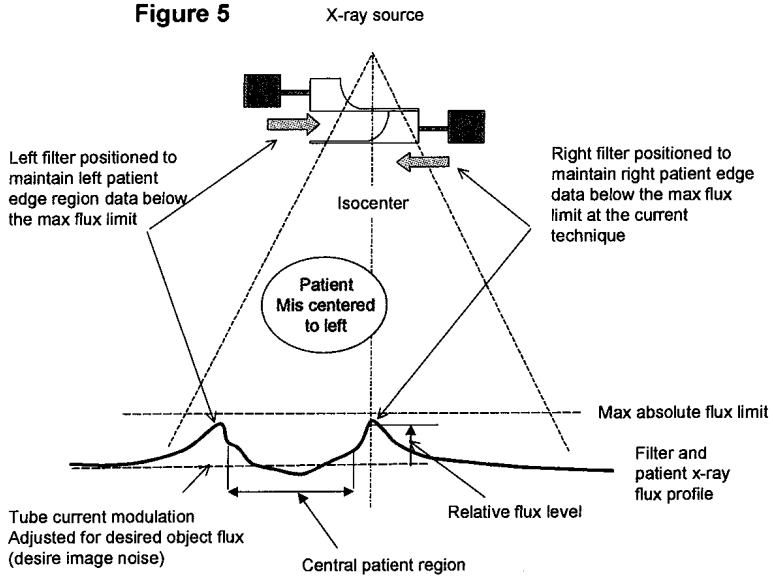

Figure 6

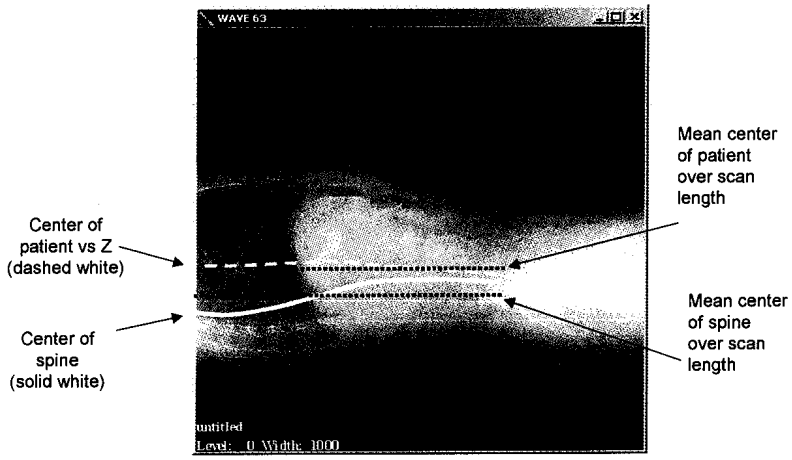

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Figure 7

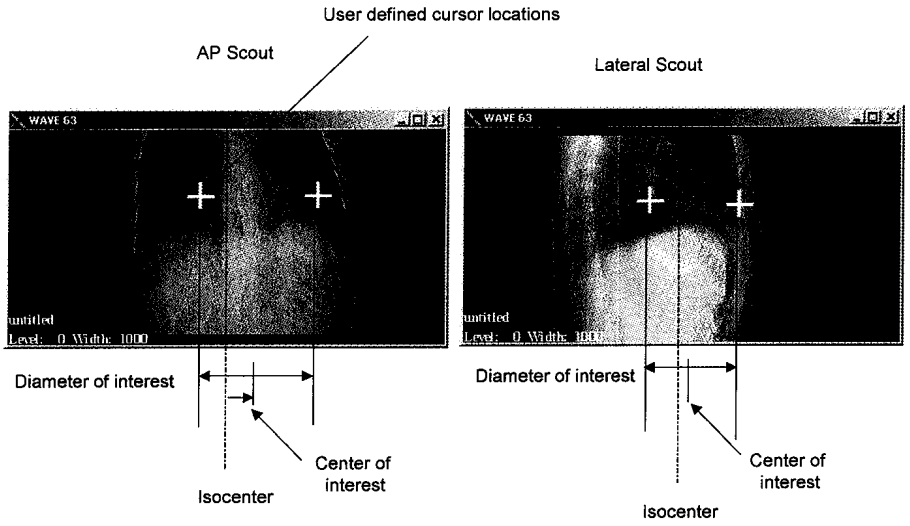

Figure 8

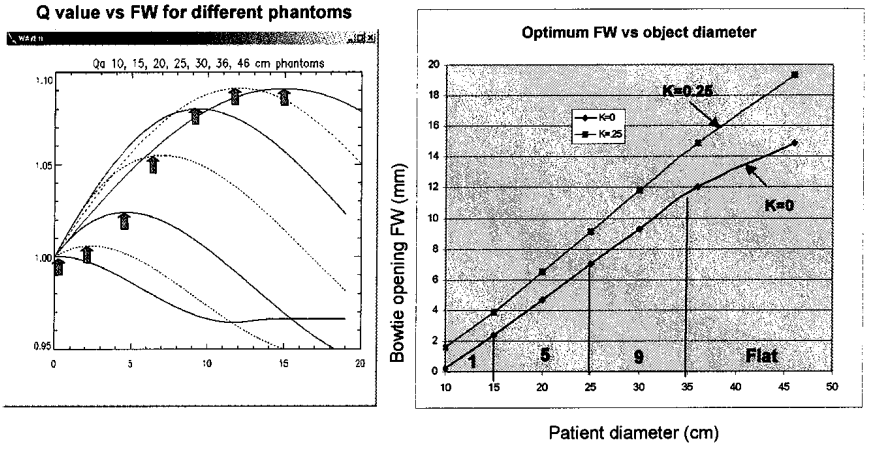

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Figure 9

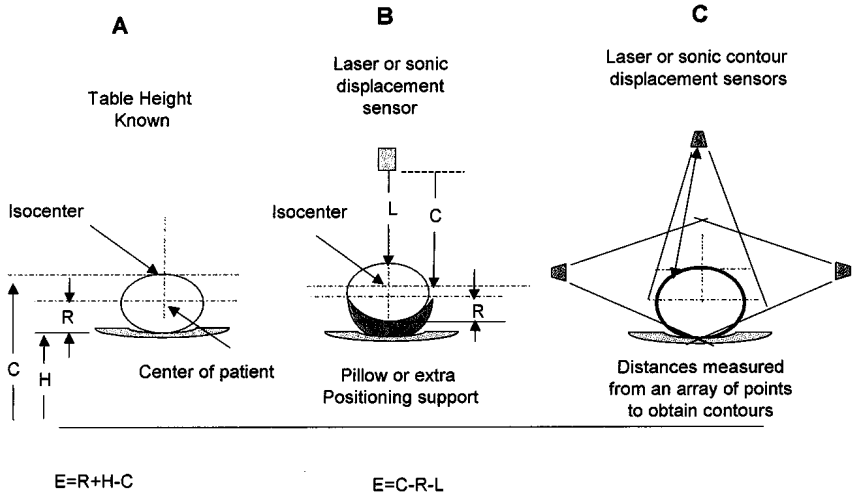
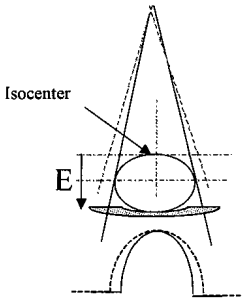


Figure 10

Eq coeff	Variable	Actual Coefficient	p	Interpret
C1	Constant	0.8760811	5.4E-150	
C2	elevation	-0.0012457	1.27E-26	Significant
C3	PA	-0.0002209	5.4E-13	Significant
C4	OVR	0.1272267	0.036253	Significant
C5	elevation*PA	-1.167E-07	5.69E-07	Significant
C6	elevation*OVR	-0.0004794	0.299104	nsignificant
C7	PA*OVR	0.0001054	1.92E-05	Significant
C8	elevation^2	-1.432E-06	4.54E-08	Significant
C7	PA^2	3.076E-08	0.34411	nsignificant
C10	OVR^2	-0.0658213	9.35E-11	Significant
C11	elevation*PA*OVR	2.081E-07	0.028178	Significant
C12	elevation^2 *PA	1.127E-09	0.01381	Significant
C13	elevation^2 *OVR	2.645E-06	5.19E-05	Significant
C14	PA^2 *elevation	8.629E-11	1.11E-05	Significant
C15	PA^2 *OVR	-6.298E-09	0.041395	Significant
C16	OVR^2 *elevation	8.599E-05	0.024166	Significant
C17	OVR^2 *PA	-1.862E-05	0.000239	Significant
C18	OVR^3	0.0105553	2.1E-14	Significant

Statistics	
Std Err	0.011
R-sq	96.03%
R-sq(adj)	95.60%
R-sq(pred)	94.84%
Press	0.026

Calculate the projection error Ratio and fit it to a cubic function Of Elevation, PA and OR to Determine equation coefficients



E – table elevation relative to isocenter (assumes object rests at a height E)
P- PA (projection area)
O – OVR oval ratio a/b a- x length, b- y length

PA correction Equation

$$PA=P/(C1+c2*E+C3*P+C4*O+C5*E*P+C6*E*O+C7*P*O+C8*E^2+C9*P^2+C10*O^2+c11*E*P*O+C12*E^2*P+C13*E^2*O+C14*P^2*E+C15*P^2*O+C16*O^2*E+C17*O^2*P+C18*O^3$$

INVENTORS *(Print or Type Name Below)*	*(Full Signature Below)*	GE	NOT GE	DATE
* Thomas L. Toth		X		
David M. Hoffman				

* = Primary Contact Inventor (to coordinate with Patent Evaluation Board and Preparing Attorney)

Read and Understood By:

2 WITNESSES (Mandatory) *(Print or Type Name Below)*	*(Full Signature Below)*	DATE

ADVANTAGES OF THE INVENTION: *Describe the benefits of the invention, both in technical terms (e.g., stronger, new application, faster imaging, etc.) and business terms (e.g., cost savings, product efficiency, etc.).*

Dose efficiency improvements up to 45% over present Lightspeed are possible with proper bowtie filter selection for large patients

Effectively increases useful tube output by 70% with proper positioning and bowtie size selection for the patient

Significant marketing value since no other vendor auto selects the optimum filter and patient centering

Provides a practical solution to a major obstacle (photon counting pileup) that currently prohibits the use of photon counting and EDCT detectors for CT

Corrects significant noise prediction errors which compromise the use of automA for small patients

PRIOR ART: *List all references to previous work that you have identified that relate to the invention (if any). Examples would be existing patents (whether GE or other) possibly identified via patent searches, GEMS invention disclosures in process or otherwise, existing products, publications, internal publications, or Tech Notes etc. All identified prior art references must be attached to this disclosure, but those pages need not be signed.*

Nov 19, 1993, US 5400378, Dynamic dose control from projection data (Z tube current modulation)

Nov 19, 1993 US 537933, Variable dose application from orthogonal projections (X,Y modulation)

June 2, 1994 US Patent 5457724, Patient Centering and DFOV determination from scout data

Sept 6, 1994 US 5450462, Increasing tube current modulation depth with generator limitations

Dec 27, 1999 US 6269501, Automatic dynamic patient positioning

May 15, 2002 Docket 125908, Organ specific bowtie addition

June 11, 2002 Docket 120219, Morphing bowtie filter

Aug 16, 2002 Docket 122942, AutomA and Smartscan parameter determination from patient projections

Sept 22, 2003 Docket 1442221,Bowtie filter with continuously variable opening

CLAIM OF NOVELTY: *Describe what is novel, unique, non-obvious about this invention compared to previous designs or solutions identified in the Problem/Background or Prior Art sections. "Obvious" is defined with respect to an individual with an average working knowledge of the general area. Be careful: what is obvious to you, as a specialist, may not be obvious to someone with an average working knowledge. You should err on the side of assuming that your invention is non-obvious.*

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Method to dynamically adjust the positioning of a continuously variable bowtie filter and the modulation of tube current
- Adjust filter position vs trend of x ray flux from previous projections
  - Trend can be estimated from scout or scouts to avoid real time attenuation surprises
    - Adjust filter postion to avoid x-ray flux rates beyond limits of detector
    - Adjust filter position relative to the flux rate of the central object region
    - Adjust mA from flux trends to maintain a desired image noise
    - Adjust mA to avoid x-ray flux rates beyond limit of detector
- Adjust initial filter position and tube current based on scout projections
- Adjust filter position dynamically to follow a miscentered patient
- Adjust filter position dynamically to follow a user identified organ of interest

Method to determine patient centering from orthogonal scouts using centroid calculations

Method to determine centering and diameter of an organ of interest
- User interactively designates locations
  - marks locations on scout images
  - marks multiple locations to indicate changing locations in Z
  - Interpolate between marked locations

Method to correct automA PA estimation errors resulting from patient miscentering

Method to determine the bowtie filter opening (FW) for optimum dose efficiency as a function of object diameter
- Determine the FW that maximizes a Q factor value for a given object diameter (d)
  - Using a Q factor with a weighted contrast contribution (k)

$$Q = \frac{KC(d, FW)}{N(d, FW)\sqrt{D(d, FW)}}$$

  - Where Noise is calculated or measured
  - Where Dose is calculated or measured
  - Where d is the mean of the elliptical axes parameters a and b
  - Where a and b are the major and minor axes of an ellipse
  - Where diameter d can be estimated from $d = avg(PM/\mu)$ when orthogonal scouts are avaliable
    - Where $\mu=0.2$ except $\mu=0.24$ for the head, *and* $\mu=0.24$ for the chest
  - Were d can be estimated from the PM and OR when a single scout is available
    - $d=(PM/\mu)(OR+1)/2$
- Determine an equation for FW vs object diameter
  - $FW = 0.45\ (d-10)$

Method to determine bowtie opening (FW) as a function of object centering error e
- $FW = 0.45\ (d-10+2ew)$
  - e= centering error
  - w = weighting function to minimize dose increase

Method to calculate an mA boost for automA (z axis modulation) as a function of patient centering error e
- $g(1.0 + 0.15\ e\ w$
  - e= centering error
  - w = weighting function to minimize dose increase

Method of selecting the optimum discrete bowtie from finite set of fixed opening bowtie filters

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A preferred set of discrete bowtie filters is FW1, FW5, FW9, and flat
Use the expression *(d-10+2ew)* to index the nearest discrete filter in a table
FW 1 < 15, FW 5 (15 to 25), FW9 (>25 to 35) and flat (>35)

Method to determine the Y axis centering error when only an AP scout is available
Using an elevation reference to the surface of the patient and the patient radius determined from the PM
E=R+H-C where E = centering error, R = patient radius, H = table elevation, C =distance to iso
E=C-R-L where L = laser displacement measurement , C =laser displacement to iso

Method to determine patient size and X ,Y centering without any scout projection information
Use laser sensors to measure the patient dimensional contour and position in gantry
Use sonic sensors to measure the patient dimensional contour and position in gantry

Method to determine the PA from patient dimensional contours
Calculate area from contour outline and multiply by μ for associated anatomy
Where $\mu=0.2$ except $\mu=0.24$ for the head, *and* $\mu=0.24$ for the chest
Method to determine the PM from patient width and lengths
Width and lengths determined from patient dimensional contours
Multiply width and lengths by μ for associated anatomy

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SUMMARY QUESTIONS FOR INVENTION DISCLOSURE

(The answers to these questions will help the modality PEB with the patent filing decisions they make.)

1) **DESCRIBE ANY RECENT WORK ON DEVELOPING AND DEMONSTRATING THE IDEA AT GEMS.** *Has feasibility been proven? How? Is there a prototype?*

Six sigma project 113673 - VCT bowtie design

2) **ARE THERE ANY PLANS TO USE THE INVENTION IN A PRODUCT?** *Give Product/Program name and milestone dates if known. Has this invention been identified as a program deliverable?*

Discrete bowtie filters FW 1, FW5, FW 9 and flat will be used in VCT, ME estimated FW10 2004. Automated discrete filer selection is a VCT program goal. AutomA improvements to compensate for centering errors will be recommended to all products currently using automa as soon as possible.

3) **WHAT ARE THE PLANS OR DESIRES TO PUBLISH?** *It is absolutely critical to identify the earliest possible public disclosure of the invention for legal reasons. This may include publication, installation of prototype, trade shows, etc. GEMS can lose the right to patent an invention by premature public disclosure.*

None at this time.

4) **DESCRIBE ANY KNOWN RELEVANT COMPETITOR ACTIVITY.** *Are any competitors working on solutions to the same problem? Have any competitors addressed the same problem?*

None known.

5) **WAS THIS INVENTION DEVELOPED IN THE COURSE OF A PROJECT WHICH WAS FUNDED IN PART BY AN ENTITY OTHER THAN GE?** *Has any work been done, for example, with Government funding, university collaboration, even if such funding was provided indirectly, as via CRD?*

No.

6) **WHAT IS THE EARLIEST TANGIBLE DOCUMENTATION OF THIS INVENTION?** *Is it a lab notebook, engineering report, etc., or this disclosure document? If not this document, please provide a reference and a date.*

This disclosure document.

7) **HOW MUCH DIFFICULTY WOULD A COMPETITOR EXPERIENCE IN TRYING TO DESIGN AROUND THIS INVENTION?** *Are there many ways of relatively equal difficulty to solve the problem, or is the invention a unique solution in terms of benefit and simplicity?*

Highly difficult if not impossible.